

**THE ROLE OF FRETTING CORROSION AND FRETTING FATIGUE
IN AIRCRAFT RIVET HOLE CRACKING -
A STATUS REPORT ON TWO FAA GRANT PROGRAMS***

Charles B. Elliott III

Mark Moesser

David W. Hoepfner

Quality and Integrity Design Engineering Center

University of Utah

Salt Lake City, Utah

5/7-39

23111

p. 6

SUMMARY

Personnel in the Quality and Integrity Design Engineering Center (QIDEC) at the University of Utah are working under a two year grant from the FAA to better understand the role of fretting corrosion and fretting fatigue in aircraft rivet hole cracking. The current program follows a one year grant program which was completed in 1993. This paper provides a status report on the results of these grant programs.

Recent effort has been focused on developing basic fretting fatigue models which consider variation in the coefficient of friction with time and location within the fretting interface. This is a very important characteristic of the QIDEC model because coefficient of friction varies significantly during the fretting fatigue process. Copies of QIDEC documents discussed in this paper can be obtained by contacting the authors.

INTRODUCTION

Fretting is a process in which two bodies in contact are subjected to relative motion of an amplitude small enough to allow resulting debris to be trapped between the contacting (faying) surfaces. Because the faying surfaces and debris are subject to corrosion as well as wear, the process is sometimes called fretting

* The FAA has supported this work through Grants No. 92-G-004 and No. 93-G-068. QIDEC is grateful for this support and the efforts of the FAA Grant Monitor, Dr. Thomas Flournoy.

corrosion. When one or both of the bodies also undergo cyclic tensile (fatigue) loading, the process is called fretting fatigue. The simultaneous action of wear, corrosion and fatigue mechanisms often results in a synergistic degradation of the components with a reduction in life which can be an order of magnitude more than would be expected based upon the operation of only one of the three mechanisms.

Fretting fatigue is increasingly being recognized in the aircraft industry as a major cause of failure. It is a failure mechanism which frequently leads to high maintenance and inspection costs and could potentially lead to catastrophic failure of aircraft components. Thus, it represents both a durability and a safety problem. Costs associated with fretting fatigue are significant. The 1988 Aloha Airlines disaster focused new attention on fretting in the aircraft industry as it was thought fretting could have played an important role in that failure.¹ Fretting can be present in any area of an aircraft structure (e.g. engines, aircraft primary and secondary structure, and landing gear components) in which small amplitude cyclic slip between adjacent contacting materials is possible. Rivets and mechanically fastened joints in general are particularly susceptible to fretting and fretting fatigue multiple-site damage. This damage can link up in aircraft structures and create catastrophic results. Thus, it is imperative to understand the role of fretting and fretting fatigue in producing multiple-site damage in riveted aircraft joints.

RESULTS FROM THE PREVIOUS GRANT PROGRAM

Based on a search of government and private literature from 1960 to 1992 a report was prepared. This report, "Literature Review and Preliminary Studies of Fretting and Fretting Fatigue Including Special Applications to Aircraft Joints" has been submitted to the FAA and is being considered for publication as an National Technical Information Service document.

The aircraft industry needs the ability to predict the role and influence of fretting on the fatigue life of riveted joints. For this reason, an extensive effort was started during the previous grant program and is continuing during the current program to improve quantitative prediction of fretting fatigue in aircraft joints. Due to the complex geometry of such joints, an accurate quantitative analysis could best be performed with the use of finite element methods.

QIDEC personnel presented four papers at the International Conference on Fretting Fatigue held in Sheffield, England in April 1993. These papers which will be published by the European Structural Integrity Society are as follows:

- Mechanisms of Fretting Fatigue (invited keynote paper) by Dr. Hoeppepner.
- The Role of Normal Pressure in Modeling Fretting Fatigue by Dr. Adibnazari and Dr. Hoeppepner.
- Finite Element Model of Fretting Fatigue With Variable Coefficient of Friction Over Time and Space by Mr. Moesser, Dr. Adibnazari and Dr. Hoeppepner.
- A Fretting Fatigue System Useable in a Scanning Electron Microscope by Dr. Elliott and Dr. Hoeppepner.

Additionally, Dr. Hoeppepner and Dr. Adibnazari co-authored a paper titled "Fretting Fatigue in Aircraft Joints" which Dr. Hoeppepner presented to the June 1993 International Committee of Aeronautical Fatigue in Sweden.

OVERVIEW OF THE CURRENT GRANT PROGRAM

QIDEC is currently working under FAA Grant 93-G-068 which was received in late September 1993 and will last two years. The objectives of the program are as follows:

- Construct, calibrate and verify a computer simulation model of a riveted joint.
- Perform a sensitivity study on some parameters which could influence fretting fatigue in riveted aircraft joints.
- Model the nucleation of fretting damage at riveted aircraft joints.
- Establish a design method that will allow an assessment of the likelihood that the fretting fatigue damage threshold will be exceeded.
- Conduct an assessment of the design approaches used by industry to alleviate fretting corrosion and fretting fatigue.
- Develop experimental techniques that allow assessment of fretting fatigue in riveted joints.
- Make all methods and findings applicable to a global aircraft reliability model.
- Maintain liaison with FAA technical personnel, other FAA programs, aircraft industry activities and ASTM activities with respect to fretting.

To accomplish these objectives, the program has been organized into the following major tasks:

- Develop and verify basic fretting fatigue models which consider variation in the coefficient of friction with time and location within the fretting interface. This is a very important (and to our knowledge a unique) characteristic of the QIDEC model because coefficient of friction varies significantly during the fretting fatigue process.

- Determine the coefficient of friction and faying surface sealant materials data necessary as input to the models.
- Plan and conduct a sensitivity study on some of the parameters which affect fretting fatigue in riveted aircraft joints.
- Plan and conduct an examination of riveted joints used in service.
- With knowledge gained from the basic fretting fatigue models, develop and verify a fretting fatigue model of a riveted joint.
- Use the results of this program to develop fretting fatigue design methods useful to the aviation community.
- Report results of this program to the aviation community through the FAA and the open literature.

This is one of several research programs being conducted by QIDEC that are leading to improved understanding throughout the aviation community of the adverse synergistic effects of wear, corrosion and fatigue mechanisms on aircraft structural integrity. Related research is being conducted for the Boeing Commercial Airplane Company and the Boeing Defense and Space Group in coordination with the U. S. Air Force. Non-aviation programs funding fretting-related research within QIDEC, which will indirectly benefit the aviation industry, include an orthopedic implant designer and a manufacturer of truck and trailer hubs.

STATUS OF THE PROGRAM

Major advances are being made in development of the basic fretting fatigue model. Recent activity included the transition from the ANSYS finite element program, used in preliminary work under FAA Grant No. 92-G-004, to the ADINA program. This switch was necessary to take advantage of the increased capability of the ADINA code available at the University of Utah. Two and three dimensional models were constructed using the ADINA code. These models were used to verify that the commercially available ADINA program can be used with the methods being developed by QIDEC. As part of this work, Fortran and C-shell codes were developed which proved the applicability of planned analytical methods for predicting changes in coefficient of friction as a function of time and location between the fretted surfaces. Basic fretting fatigue model development activities will continue with emphasis on incorporation of materials data when it is determined.

Development of the experimental methods and hardware to determine the coefficient of friction and faying surface sealant materials data necessary as input to the models is progressing on schedule. A rough

analysis of a riveted joint was conducted to determine the expected variability of normal surface tractions and relative displacements within a riveted joint. From this analysis it was determined that coefficient of friction data are desirable for relative slip an order of magnitude less than that reported in the literature. Collecting such data will present a challenge, but one which we are working to meet. Significant effort was expended developing and analyzing possible methods for determining coefficient of friction data at relative displacements as low as two microns. A preliminary test apparatus design was developed and is being refined. Methods and equipment for conducting faying surface sealant tests also will be developed.

QIDEC is in the process of developing a partnership with an industrial representative to help with planning the "sensitivity study on parameters important to fretting fatigue in riveted aircraft joints", and the "examination of riveted joints used in service" portions of the program. We are optimistic that such a partnership will be beneficial to both parties.

As part of the requirement to maintain liaison with the FAA and other aircraft industry activities, QIDEC personnel attended and made presentations at the FAA/NASA conferences in November 1993 at Lehigh University and March 1994, when QIDEC was the host organization. Additionally, QIDEC representatives attended the December 1993 USAF Structural Integrity Program Conference, where the Director of QIDEC made a presentation.

CONCLUDING REMARKS

The Quality and Integrity Design Engineering Center is pleased to have the opportunity to conduct this important research for the FAA and the aviation community in general. We will make every effort to disseminate our findings as they are developed.

REFERENCE

1. Brewer, John C.: Fretting Issues for the Aging Aircraft Program, U.S. DOT/FAATC, Oct. 1991.

BIBLIOGRAPHY OF QIDEC REPORTS AND PAPERS

Copies of the following reports and papers can be obtained by providing your name and address to Dr. Charles B. Elliott, III, University of Utah, Department of Mechanical Engineering, Merrill Engineering Building Room 3209, Salt Lake City, Utah 84112; phone: (801) 585-6429; FAX: (801) 581-8692; email: elliott@me.mech.utah.edu.

- Hoeppner, D. W., Adibnazari, S. and Moesser, M. W.: Literature Review and Preliminary Studies of Fretting and Fretting Fatigue Including Special Applications to Aircraft Joints. Submitted to the FAA in November 1993.
- Hoeppner, D. W.: Mechanisms of Fretting Fatigue. Invited keynote paper presented at the International Conference on Fretting Fatigue, Sheffield, England, April 1993.
- Adibnazari, S. and Hoeppner, D. W.: The Role of Normal Pressure in Modeling Fretting Fatigue. Presented at the International Conference on Fretting Fatigue, Sheffield, England, April 1993.
- Moesser, M. W., Adibnazari, S. and Hoeppner, D. W.: Finite Element Model of Fretting Fatigue With Variable Coefficient of Friction Over Time and Space. Presented at the International Conference on Fretting Fatigue, Sheffield, England, April 1993.
- Elliott, C. B. III and Hoeppner, D. W.: A Fretting Fatigue System Useable in a Scanning Electron Microscope. Presented at the International Conference on Fretting Fatigue, Sheffield, England, April 1993.
- Hoeppner, D. W. and Adibnazari, S.: Fretting Fatigue in Aircraft Joints. Presented to the International Committee of Aeronautical Fatigue in Stockholm, Sweden, June 1993.